Ecological Assessment of Aspen Communities in the Klamath Network: A Problem Analysis

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Sarah McCullough[1]

Dr. Kenneth W. Tate[1], Principal Investigator

1. Department of Plant Sciences, University of California, Davis, California

Abstract

This study will evaluate the loss of plant diversity from aspen stands which are in decline due to conifer encroachment at Lassen Volcanic National Park, California. It will quantify the amount and overall rate of conifer encroachment into 36 aspen stands from aerial photographs taken in 1952 and 2005 using remote sensing methods. We will block by enrolling 12 stands from each of the three major aspen areas at Lassen (n=12 per strata, N=36). We will stratify the blocks by cover class, and randomly select stands to represent the gradient of conifer cover occurring within the area (e.g., 25 to 100% conifer cover). During the summer of 2007 we will measure conifer cover and understory diversity within each aspen stand using a modified Whittaker plot design ($1000m^2$). We will then attempt to correlate current plant diversity to: 1) change in conifer density and area from 1952 to 2005; and 2) current conifer cover. These measures will describe the current resource that is at risk of loss, and the rate at which it is changing. It will provide managers with the information needed to maintain aspen stands and the understory diversity associated with them.

Keywords: *Populus tremuloides*, understory diversity, keystone, photointerpretation

Problem statement

Aspen stands provide an important source of understory plant diversity in the conifer dominated forests of Lassen Volcanic National Park (LAVO), and may be considered a keystone species. However, studies indicate aspen are declining in the region (DiOrio et al, 2005) and throughout the West (Bartos and Campbell, 1998). Preliminary results from an aspen inventory and assessment of LAVO indicate a similar trend. Most stands are small in size (median size of currently mapped stands is 0.135 hectare), heavily browsed by deer, and experiencing moderate to high levels of conifer encroachment. The implication is that as aspen stands decline in area, the understory plant diversity harbored beneath them is lost. Few studies have sought to measure loss of plant diversity from aspen stands in decline. This study will quantify the amount and rate of conifer encroachment in 36 aspen stands at LAVO over the period 1952-2005, and will measure current levels of understory diversity in aspen stands over the local range of conifer encroachment. It will describe the amount of biodiversity that is at risk of loss, the rate at which it is changing, and evaluate the association between conifer encroachment and understory diversity. This approach will provide managers with the information needed to stabilize changing aspen communities at LAVO.

Background

One justification for active aspen management is that aspen has been described as a keystone species by several authors (Bartos, 2001; Campbell and Bartos, 2001). The presence of aspen supports and maintains levels of biodiversity that would otherwise not be present (Manley and Schlesinger, 2001; Potter, 1998). Kuhn (2007) found a mean species richness in 30 northern Sierra Nevada aspen stands of 41 species, compared to a mean of 22 species in conifer. In a comparison of aspen and conifer communities, 76% of species were unique to one community. Aspen provide ecological services such as forage, habitat for many plant and animal species (especially birds), and increased soil water availability (Sheppard et al., 2006). Stohlgren (1997) described aspen as a keystone ecosystem, containing "high plant species richness, distinctive species compositions, or distinctive ecological processes that benefit many other species and ecosystems." In light of this usage and current interest and concern about park aspen resources, the keystone designation could certainly be applied to aspen at LAVO.

Aspen exhibits a clonal lifestyle, and requires disturbance to periodically trigger vegetative reproduction. Mature clones produce profuse numbers of seeds, but the stringent requirements for seed establishment (truncated seed viability, bare mineral soil, warm temperatures and constant moisture in the first growing season) result in infrequent seed establishment. Aspen relies on vegetative suckering from the root system to maintain clones over the long periods between successful establishment events. Fire plays an important role in triggering vegetative reproduction in aspen. New shoots are released when a disturbance, such as fire, kills or stresses mature aspen stems and disrupts shoot apical meristem hormonal dominance. Aspen is a shade intolerant species; shoots require stand openings to persist, and mature stems perish if they are overtopped by other tree species (Sheppard et al., 2006).

Anthropogenic alterations to natural disturbance regimes have reduced the frequency of events that stimulate vegetative regeneration. The policy of fire suppression removed fire as an integrated ecological process from the landscape. At LAVO, all fires were suppressed from 1905 until the development of prescribed fire management, and fire is still occurring at much smaller spatial scales than in the past (Taylor, 1997). Fire suppression has also resulted in fundamental shifts in forest stand density and structure across the West, as mature forests fill in with younger age classes of shade tolerant conifer species such as white fir (*Abies albicaulis*). As the encroaching conifers overtop the shade-intolerant aspen, stands transition to climax fir forest.

Herbivore pressure further impacts vegetative regeneration. Kay and Bartos (2000) showed that aspen subjected to deer and elk herbivory did not regenerate successfully or regenerated at much lower stem densities than stands protected by exclosures. At LAVO, aspen stands show evidence of impact from both deer and beaver (*Castor canadensis*) herbivory. Deer browsing on aspen suckers is reported to be nearly 100% of current year growth in the majority of aspen stands (Nancy Nordensten, personal communication). Most beaver use is seasonal within LAVO, and there is an established colony in Warner Valley. Aspen is an important food source for beaver (Shepperd et al., 2006), and beaver can have a major impact on individual aspen stands (Beier and Barrett, 1987). An aging or overtopped aspen stand will produce new shoots annually, but without a release from the double pressure of conifer shading and herbivory on new growth, a clone will die as the carbohydrate stores of the root system become depleted. The death of the clone results in the loss of the ecological services provided by aspen.

Current environmental trends in aspen populations have been studied using stand level studies of age class structure, photo point analysis of historical photos, and GIS-based landscape level change detection studies. With some exceptions (Kulakowski et al, 2004), the majority of these observations have found a widespread decline in aspen. Aspen stand surveys from the Rocky Mountains have shown that many stands are currently dominated by mature to decadent trees and lack younger age classes, indicating poor or unsuccessful regeneration (Mueggler, 1989; Bartos and Campbell, 1998). In southwestern Montana, Wirth et al. (1996) overlaid maps of the current extent of aspen with the historic extent using aerial photos in a GIS, and found a 45% decrease of aspen over 45 years. In California, DiOrio et al. (2005) found a 24% decline in aspen stand area over a 48 year period in the Warner Mountains. A similar pattern was observed adjacent to LAVO on the Lassen National Forest, Eagle Lake Ranger District, where 77% of stands were found to be in decline, defined as an almost complete loss of mature aspen with little or no regeneration (Jones et al., 2005).

Objectives and Hypotheses

This study is designed to:

1. Quantify the amount and overall rate of conifer encroachment from 1952-2005 in aspen stands using remote sensing methods.
   - We hypothesize that conifer density and conifer cover have increased in aspen stands over the period 1952-2005.

2. Examine the association between the degree of conifer encroachment and understory diversity in aspen stands over the full range of encroachment levels.
   - We hypothesize that current understory diversity will be negatively associated with current conifer cover.
   - We hypothesize that current understory plant diversity will be lowest in stands with the highest rate of increase in conifer density and cover from 1952-2005.

The study will not attempt to predict the historical understory diversity of aspen stands in 1952, since it is not possible to know whether understory diversity in 1952 was the product of a lesser degree of encroachment or of other disturbance or climatic factors. The study will determine the amount and rate of change in conifer encroachment into aspen stands over the last 50 years, and will measure current levels of understory diversity in stands over the full local range of encroachment. These measures will describe the current resource that is at risk of loss, and the rate at which it is changing.

Study Area

Lassen Volcanic National Park straddles the transition zone between the Northern Sierra Nevada and Southern Cascade mountain ranges. Elevation ranges from 5,400 feet to over 10,000 feet. Lassen Peak is the highest mountain at 10,457 feet and is the southernmost volcano of the Cascade Range. The summers are dry with occasional thunderstorm events; winters are harsh with deep snowpack formation. The two most prominent forest types at the elevations where aspen are found are yellow pine (*Pinus ponderosa* and *Pinus jeffrei*) and red fir (*Abies magnifica*) types. Most aspen stands at Lassen occur within three areas: Warner Valley, the Devastated Area, and the Butte/Snag Lake region. These three areas provide the study areas for this work.

In the Warner Valley a series of aspen stands are found along the entire length of the valley from Devil's Kitchen to the park boundary. The last period of glaciation, which ended around 10,000 BCE, was the last major geologic disturbance in Warner Valley. The mixed hydrologic regime of the valley consists of one perennial stream fed by snowmelt and a series of springs that emerge from beneath the basaltic cap of the valley walls. The springs support a series of wetlands, including a significant fen resource in Drakesbad Meadow. Warner Valley was first settled in the 1890s by homesteaders, and it is the site of a historic resort currently operated by a concessionaire for the National Park Service. Elevations range from 5400-6400 feet.

The Devastated Area includes one of the largest concentrations of aspen stands in the park. It derives its name from the catastrophic mudflow at the height of the eruptions of Lassen Peak in May 1915. All vegetation in the area, mature forest before the mudflow, was removed. The ground was covered in a coating of ash and debris 2 to 6 feet deep in most places, but reached a depth of 30 feet in a few locations. A study of the area in 1963, forty eight years after the disturbance, recorded the occurrence of aspen in several study plots above and below Hat Lake (Bailey, 1963). The 1952 photos show that many parts in the affected area still appeared to lack vegetation. Elevations range from 6000-6400 feet.

In the northeast corner of LAVO, aspen stands are found along the east sides of both Snag Lake and Butte Lake. The area last experienced significant geologic disturbance in the mid 1700s, when lava flowing from the nearby Cinder Cone dammed the Butte Lake drainage and formed Snag Lake. Elevations range from 6000-6200 feet.

Study Design and Analysis

This is an observational study. The study design is blocked with enrollment of an equal number of aspen stands from each of the three major aspen areas at Lassen (Warner Valley, Devastated Area, and Snag-Butte Lakes). The study areas represent the majority of the aspen population at Lassen, and include the full range of stand conditions, from larger, relatively intact stands, to small, heavily encroached stands in decline. The study areas were blocked due to their differences in history of volcanic activity and geographic characteristics. We will enroll 12 stands per area into the study for a total of 36 stands. A selection filter will be applied to limit the population of this study to aspen stands in the three study areas that have not experienced either significant recreational impact or fire disturbance in the past twenty years. To stratify for the gradient of conifer cover, we will delineate conifer cover classes, and randomly select an equal number of stands from the pool of stands for each class. Stratification will reduce bias towards larger, intact stands. A linear mixed effects analysis approach will be used to test if mean conifer density and cover across stands in 2005 is greater than in 1952. An LME approach is used to account for variance structure and dependence introduced in the dataset due to repeated measures on each stand. Multi-variate analysis techniques will be used to test and model associations between the degree of conifer encroachment in stands and aspen understory plant diversity. Deer browse, stand size, available plant light, elevation, distance to nearest stream, slope, and aspect will be treated as covariates in this analysis.

Stand Selection
In each of the three study areas, fifteen to twenty aspen stands will be identified as candidates for enrollment in the study and plot-based data collection. These will include stands previously mapped by the park, stands identified from aerial photographs, and stands from preliminary field surveys at the beginning of the field season. The preliminary field surveys are intended to identify additional potential stands and to delineate classes by conifer cover. The data collected in the preliminary field surveys will include location (taken as a GPS point), elevation, an estimate of stand size, conifer cover class, recreational impact levels, and deer browse using browse form class categories established by Keigley (1998). A selection filter for fire and recreation impact will then be applied to the pool of stands. Both fire and recreation may have a significant localized effect on understory plant species. Other criteria (stand size and deer browse) were considered for the selection filter. Stand size was ruled out because restricting stands to a minimum size will bias the selection towards the few large aspen stands at Lassen. Deer browse was ruled out because it is evident in almost all aspen stands. These characteristics will be measured as covariates. Of the stands remaining after filtering, we will randomly select an equal number of stands for each class, for a total of 12 stands per block. The number of stands per class will depend on the number of classes delineated. All sites selected will need to be in areas with adequate imagery coverage for the corresponding change detection analysis.

Field Data Collection
We will use a modified Whittaker plot design (ten $100m^2$ plots in a grid formation and twenty $1m^2$ plots nested in the grid) developed and used by Keely et al. (2003) to allow the measurement of species composition and diversity at 1 m^2 scale and species richness at 1000 m^2 scale. In the 1 m^2 plots, understory and overstory cover measurements by species will be taken. We will also potentially collect solar radiation information using a solar pathfinder. In the 1000 m^2 plot, species presence/absence will be recorded. The center line of the plot design will be read for line transect canopy cover and strata height to describe stand structure by species and height. In addition, presence of conifer seedlings will be recorded. Stand extent will be mapped with GPS and a point will be taken to mark each plot. Slope and aspect will be measured from the center of the plot. Distance to nearest stream will be measured. All unknowns will be collected and identified to species.

Change detection – Aerial Photo Analysis

For selected stands in the three study areas, black and white aerial photos from 1952 will be georectified using a local rectification methodology. The local rectification will, for a 1-5 acre area around each target stand, stretch the photo (also known as "rubbersheeting") over the desired coordinate system (NAD 83 Zone 10N) using 6-8 ground control points around each stand and 2005 NAIP imagery as the reference image. The local rectification methodology has been selected as the most appropriate method to produce accurate measurements at the local scale of each target stand. An orthorectification methodology was not chosen since this is not a landscape scale application. The target stands will be chosen from the pool of stands known from park mapping efforts and from stands visible in the aerial photos. Due to low visibility of aspen in the photos, stands will be analyzed for measures of conifer encroachment, including cover and relative height. The higher visibility of the individual canopies of conifers relative to aspen canopies should allow an accurate measurement. In addition, acquisition of color infrared imagery will provide an extra resource in the characterization of aspen stand boundaries, and will also represent a midpoint in the study time interval.

Conclusions

Eriksson (1993) concluded that asexual reproduction effectively maintains clonal species between infrequent episodes of sexual reproduction as long as environmental conditions are relatively stable. Ultimately, sexual reproduction is necessary for species to adapt to environmental changes and to occupy new habitat. The observed decline in aspen may be the result of the interaction of significant changes in the environmental conditions of the West and the adaptive limits of the clonal lifestyle. In the National Parks, anthropogenic activities such as fire suppression have disrupted ecological processes while the desire to allow natural changes to occur unimpeded has allowed landscapes to transition to potentially unintended states through succession. Active management of aspen will be needed to maintain stands in a stable successional state. This study is intended to provide the quantitative data needed to support the maintenance of aspen ecosystems on the landscape.

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